Engineering Management in the Information Age

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Introduction

Computers have changed the way we do most things, and nowhere is this more true than in the engineering profession. Much of the tedious work of design calculations, stress calculations, and cut-fill computations have been reduced to a computer program that executes the task in seconds. Even the drafting board is fast disappearing from the scene as computer aided design and drafting replace paper and pencil. The way we collect, store, and use data is changing rapidly. Now, 3-D images are created and rotated. Dead and dynamic loads are integrated with data on wind speed and direction, and the effects simulated in real time. The time to do these complex calculations is now measured in nano-seconds.

Managing the world's largest engineering organizations in this information age presents challenges as large as we in the US Army Corps of Engineers have ever faced. This paper describes the experiences of one Federal Agency as it moves deliberately and confidently into this new era of computers and information.

Engineering management Environment

The US Army Corps of Engineers is the largest engineering and engineering management organization in the world. Its mission, dating from 1775, has been and continues to be to provide engineering support to the nation. Comprised of some 39,000 employees throughout the world, we are engaged in water resources development, environmental preservation and enhancement, military construction, research and development, and many other statutory and regulatory efforts. The diverse nature and world-wide scope of our responsibilities presents unique management challenges. The Corps is a highly decentralized organization with a headquarters, divisions (regional offices), districts (executing elements) and project or local area offices. Each district office is located close to the projects and operates with considerable autonomy.

State of Automation in the Corps

The Corps has two broad categories of automated systems: (1) scientific and engineering systems and (2) business systems. Generally, the scientific and engineering systems have kept pace with technology and are some of the most modern in the world. However, the business systems are in relatively poor shape. They are characterized by batch technology, use second generation languages, old hardware and many duplicate systems containing much of the same data. Each functional manager developed his or her own systems, in some cases complete with hardware, software, and applications. In most cases, the hardware, application and data are tied together. When a change was

made in the hardware, for example, the data and applications were both affected. When a data change was needed, there was no way to be sure that all the systems that used the same data had been changed. Furthermore, we had no clear picture of what data we had, how much it cost to maintain, who used it, etc.. In short, for an organization being propelled into the information age of the 1990s, we did not control our corporate future.

Background and Approach

In 1984 we began to review our business processes. In order to modernize our automated systems from a business perspective, we chose to pursue a business modernization approach rather than follow the traditional approach and automate existing processes. We followed the general business modernization model shown in Figure 1.

To meet our business modernization objectives, we looked for a methodology that was both complete and comprehensive. The overall approach would ultimately involve four basic phases and overlay the general steps shown in Figure 1. The four phases are:

- Strategic Planning
- Tactical Planning
- Structured Requirements Analysis
- Systems Development

For the first two phases, we adopted the IBM Business Planning approach and called it Information systems Planning (ISP) .
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This approach worked well :For the strategic and tactical planning phases. Figure 2 represents the first phase of the process.

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Our ISP studies clearly showed the problem: our standard systems did not meet management needs. Managers at all levels identified the existing finance/accounting and project management systems as deficient in meeting their mission needs. The standard systems were primarily upward-reporting tools rather than systems designed to meet day-to-day operational requirements. To fill the void, many field offices had developed their own local systems, and the so-called standard systems had been modified so extensively that no standard systems existed for management use.

This situation produced extensively duplicated systems, redundant data collection and use, and increased data entry requirements. The result was increased labor costs to develop, operate, maintain, and functionally manage information systems.

Our ISP studies recommended that future system development proceed in a more orderly and disciplined manner and involve more field office and functional managers. Most importantly, we needed to create a Corps-wide standard information architecture and then follow that architecture.

To accomplish our Corps-wide ISP objectives, we needed a tactical plan. This plan, the Information Systems Planning Implementation plan (ISPI), addressing the information needs for

the entire Command, was completed in 1985. Figure 3 shows how the ISPI efforts logically followed the initial strategic planning. Through the ISPI, we completed the first step of the general business process improvement model mentioned earlier. (Figure 1)

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This effort also produced the project slate and a series of guiding principles. The following guiding principles have remained constant throughout our business modernization efforts:

- Data is a Resource
- Data Must be Separated from Applications
- Data is Captured at the Source
- Data Must be Shared by All
- Data Must be Captured Only Once
- Collect only Minimal Essential Data
- Users Must Direct Development
- Improve Information Quality, Timeliness, and Access

During the tactical planning phase of business modernization planning, top management made three important observations about using technology to solve our problems:

1. Modern Relational Data Base technology is now capable of and flexible enough to meet user needs for timely and accurate information.

2. To take full advantage of technology capability, we would have to change our systems development approach from building "stovepipe" systems to building corporate, integrated, shared data systems.

3 . we need to develop standard data definitions and enterprise-wide models to provide the consistency needed for data sharing.

From these observations came four key decisions:

1. We created the Information Systems Modernization Program (ISMP).

2. We adopted new disciplined system development procedures.

3. A standard modeling technique (IDEF) was selected.

4. A standard RDBMS (ORACLE) was selected to facilitate data sharing.

After completing the planning phases of our modernization program, we could begin the analysis phase of our various business processes. We were ready to move to step two of the business process improvement model (Figure 1)

In 1986, we incorporated the Structured Requirements Analysis Planning (STRAP) methodology into the ISMP strategy. STRAPs provided the plans and specifications (models) for follow-on development. Figure 4 depicts how the STRAP process naturally followed the Strategic

and Tactical Planning. It was in this phase where IDEF proved valuable.

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How We Used IDEF

Since our overall goal was to improve the business processes before we automated them, we decided that our STRAP would have to consist of two parts. First, using IDEFO, we analyzed the "as-is" condition of the business process. Then we used IDEFLX to do the data modeling of the same "as-is" condition. During this modeling of the existing conditions in our business processes, we discovered that tremendous redundancy and duplication existed. Figure 5 shows the eleven key business processes that have been modeled to date. We had now completed step three of the business modernization model, the modeling phase.

- Design Management
- Construction Management
- Finance and Accounting
- Policy and Guidance Development
- Real Estate Management
- Programs Management
- Planning
- operations and Maintenance
- Life Cycle Project Management
- Consolidated Requirements

Figure 5

After completing each "as-is" model of a business process, we kept the team together to create the future state: the "to-be" model. Now that we better understood the business process and had done both activity and data modeling, we could see what we could improve. Each process was developed considering the business process improvements, and activity and data models were created for this new future state. This is step four of the business process model (Figure 1).

In the early stages of development, we had few automated tools to assist us, and much of the modeling was done by hand. Of course, there are several automated tools on the market now. In fact, we developed our own automated modeling tool, which I will discuss later.

As we developed to-be models for several business processes, we realized that we needed to integrate the various models into a single one. Building a single model has the advantage of showing where the various pieces of data are used in a corporate sense. Furthermore, since our initial objective was to create a corporate data base (at least at the conceptual level), we had to integrate the various business models. Thus was born the Command Data Model.

Command Data Model

In an effort to control what kind and how much data we collect, we developed the Command Data Model. This model is a logical representation of all the data we use in the Corps of Engineers. The model is output from the Command Encyclopedia, the "database about the database." Included

with the model is the data dictionary. We also carry control down to the physical model and external view. This is where the payoff begins to be seen.

The model and the dictionary are essential ingredients in managing and controlling the data explosion. In large organizations, such as the Corps, keeping systems current is expensive in both people and money. We saw the model as a way to simplify maintenance of systems. The model and the dictionary are living documents, always changing as new information is defined. Again, the overall flexibility of IDEF paid off. We developed the Command Data Model using IDEF; therefore, when we develop new functional requirement, we can go to the model to see if we are already collecting that data item. If we are, we don't have to collect it again. We can simply adapt it to this new requirement. If we want to change a data item or add a part of a process, IDEF allows us the flexibility to see which other applications are affected and, make the appropriate changes and modifications.

The command data model also serves as a control mechanism for changes and improvements to systems. As we move through the life cycle of automated systems, changes must be controlled and managed. The command data model serves as the central control mechanism. As mentioned earlier, to help us get the job done, we developed several tools that were state-of-the-art in their time:

- Command Data Dictionary
- PC Modeler
- Command Data Model
- Physical Models
- External Views
- Computer Systems Architectures
- Impact Analysis

All these tools are part of our Command Encyclopedia.

The model is based on the premise that data is a corporate resource and will be shared as much and as widely as possible. The great advantage of the Command Data Model is that it allows us to analyze impacts before we ever touch the physical structure.

Data Stewardship

Relational Data Base technology make data sharing a real possibility. convincing people to share data is another challenge. our approach makes people stewards, not owners, of data. This data stewardship idea is reinforced when we can see just who has responsibility for which data.

Baseline Concepts

Logically integrating the eleven business processes that had been analyzed and modeled proved to be a very valuable process. During this integration, a thread of common data elements and a logical view of work began to emerge. The integration of the "to-bell models gave rise to what later would be termed the "Baseline Concepts." These baseline concepts would prove to be the foundation upon which new systems would be designed and built. As simple as it sounds, the baseline concepts established the basic concept: work is work. Regardless of the source of funding, regardless of the nature of the effort, regardless of how it is accomplished, work is work.

To manage work, three things must be available: Scope, a defined work breakdown structure; Estimating, the development of a resource plan; and Accounting, the development of an accounting structure to measure against the plan. Figure 6 illustrates the concept.

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The last step in the process is where systems and data bases are developed. The Prototype. Development Concept (PDC) was incorporated into the ISMP strategy as the method used. PDC is the last step in our business process improvement model. More technical in nature, PDCs provides the details needed to actually build the systems defined during the STRAP. From the original slate of eight STRAPS, thirty PDCs were developed. Figure 7 shows the final phase of our process and completes the overall methodology hierarchy.

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Analyzing these PDCs led to defining the data elements that make up the Corps' Command Data Base. This analysis identified which data elements are used in different functional areas but should be shared. Initially we felt that about 15% of the data used in the Corps would be shared. During this phase we also looked at data duplication and redundancy. our original estimate was that 20% of the data was duplicated. Actually, it was close to 25%, a large amount of overlap.

Changes During Development

While the development of prototypes was in full swing, the Corps made a fundamental shift in its management approach to a fundamental part of our business. Instead of the traditional separate design and construction management approach we adopted a more structured Life Cycle Project Management approach.

Automated systems mirror the management approach. ISMP emphasis was shifted to support the Life Cycle Project Management (LCPM) concept. We immediately completed a LCPM STRAP and began PDC development.

Program Leadership and Management

In every evaluation of systems development, top management support is identified as a critical success factor. The Deputy Chief of Engineers is the senior information resource manager in the Corps. He is assisted by the Information Resources Management Steering Committee (IRMSC), composed of general officers and senior civilians from Headquarters and field offices. They represent the functional interests of the Corps. Without top management interest, involvement, and support no one can succeed in developing business systems. We proved that again! Fortunately, we have top management support and commitment.

Complexity of Effort

Events forced us to deal with three major changes in our automation operations simultaneously: installing new computer hardware, replacing old systems, and introducing new process.

1. We are replacing all of our current central mainframe computers and centralizing from twelve to two regional centers. We are also installing a worldwide communications backbone to connect all our offices.

2. We are replacing our old management systems with new systems, designed to operate in a relational data base environment. Further, we have redefined our corporate systems and reduced the number of standard systems from 89 to 47.

3. During these changes in how automation supports our business processes, we made a major change in our central business process: We instituted Life Cycle Project Management. This caused us to reevaluate all our business processes and what we were automating.

The detailed inward scrutiny of our business processes and the automation that supports that work provided new insights into just what business we are in. As a result of our movement into the information age, we have adopted new policies about information that allow us to take advantage of the information age and the economic and business opportunities it presents.

We are building the US Army Corps of Engineers Command Data Model. The model is the conceptual view of all the data the Corps needs to do its business. Selecting IDEF as our modeling methodology was an important decision that proved to be right. The resulting model and its accompanying data dictionary serve as the starting point for developing shared data systems. We believe that information not only conveys power, but that we can use shared information (data) to leverage our staff and contractors toward increased productivity.

Standard definitions of data is a continuing goal. We have a start and are adding new data items and definitions daily. Getting agreement from the functional proponents on definitions has been a major effort. If data is to be shared across functional and organizational lines, then definitions must be common.

Our new financial management system is in the final design stages. Deployment is scheduled for next summer. A newly designed real estate management system will be deployed in the spring. The new project and programs management system is in the early phases of design. Our plan is to field the new project/programs management system and the financial management system at the same time. All three share a high percentage of data, but it is only collected once: at the source. Our Encyclopedia is the tool we will use to manage and control this process.

What Did We Learn?

We learned a lot about our business and how to make changes in this governmental organization. By way of example, a couple of lessons learned will be of interest:

First and most important, we learned that although it is difficult to make major changes in the automation, it is possible. We selected a methodology (IDEF) and stuck to it. We were

tempted by shortcut, expedient methods, but held firm to the approach. Developing a data model of the enterprise both now and for the desired future is risky and difficult, but it can be done if you stay with it.

Second, changing people's minds about the absolute need to share data was more difficult than we first estimated. People naturally tend to think they own data just because they put it into a system. Logic isn't enough to convince them; they must be shown that data can be shared, that everyone can use data put in by someone else. Again IDEF played a major role. The presentation logic helped convince the reticent. We used the approach that people are the stewards of data, not owners. This requires a great deal of time and effort, but it works.

Third, the old adage of getting top management support is critical. Without strong support from the very top of the organization, success will be elusive. But it doesn't stop at the top. Functional chiefs and middle managers must be on board. We found that involving them in designing the future was the strongest argument in convincing them to participate. IDEF helped because it is a clear and straightforward approach to modeling.

Conclusions

From our work we have formed some important conclusions about engineering in the information age.

Those who survive and flourish will understand themselves and those they serve. We looked deeply into the business processes of the Corps and improved both the automation and basic business processes.

In the 1990s and beyond, information is and will be the power base. Those who understand the data they use, have good reliable data, and can act quickly to changes will have the competitive edge.

Sharing data across the organization will make information cheaper and more reliable. Source data entry and the intangible benefits of data sharing is part of our goal.

Separating the data from the hardware from the applications, while initially more work, will give maximum flexibility. Each time one component changes the entire process will not have to be redesigned.

Engineering in the information age will be more exciting than ever before. The computer offers the promise of taking much of the drudgery out of engineering work. It hold the promise of more flexibility and power for us to make choices. But as always, the future belongs to those who are prepared. We in the Corps are prepared: Essayons!